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ANTI-FOG SOLUTION FOR AIR-PURIFYING RESPIRATOR LENSES

Karen M. Coyne

RESEARCH AND TECHNOLOGY DIRECTORATE

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ABERDEEN PROVING GROUND, MD 21010-5424

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14. ABSTRACT
The anti-fog efficacy of a topical surfactant solution (3 g of Pluronic F127 Block Co-polymer Surfactant powder mixed in 100 mL of distilled water) was assessed. Each of three respirators was tested three times with treated and untreated lenses. Each mask was placed on a heated (32 °C), wetted headform in an environmentally controlled room (21.5 °C, 25% RH) for 10 min. Miniature cameras mounted in the headform captured images through the respirator lenses. These images were then processed using a custom software program that specified the Snellen visual acuity based on the amount of lens fogging. Average Snellen visual acuities for the untreated left and right lenses were 20/254 and 20/261, respectively. For the treated lenses, average acuities were 20/6 and 20/5 for the left and right lens, respectively. Thus, the tested surfactant solution decreased lens fogging of an air-purifying respirator.

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PREFACE

The work described in this report was authorized under Job Order No. 7R22GA. This work was started in August 2007 and completed in October 2007.

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ANTI-FOG SOLUTION FOR AIR-PURIFYING RESPIRATOR LENSES

1. INTRODUCTION

Fogging of respirator and protective eyewear lenses occurs when water vapor condenses on the surface of the lens. Topical coatings, such as surfactants, may be applied to the lens surface to prevent condensation from forming. The goal of the current effort was to investigate the efficacy of a topical solution of Pluronic F127 block co-polymer surfactant (BASF Corp., Mount Olive, NJ) in either preventing or decreasing lens fogging on a full-facepiece air-purifying respirator (APR). This evaluation was conducted as part of The Technical Collaborative Program Technical Panel (TTCP-TP11) effort with the Defence Science and Technology Laboratory (DSTL, Porton Down, United Kingdom), which supplied the anti-fogging compound for testing.

2. METHODS

2.1 Test System

The test system consisted of a custom-developed image acquisition system and image processing software as shown in Figure 1. [1,2]

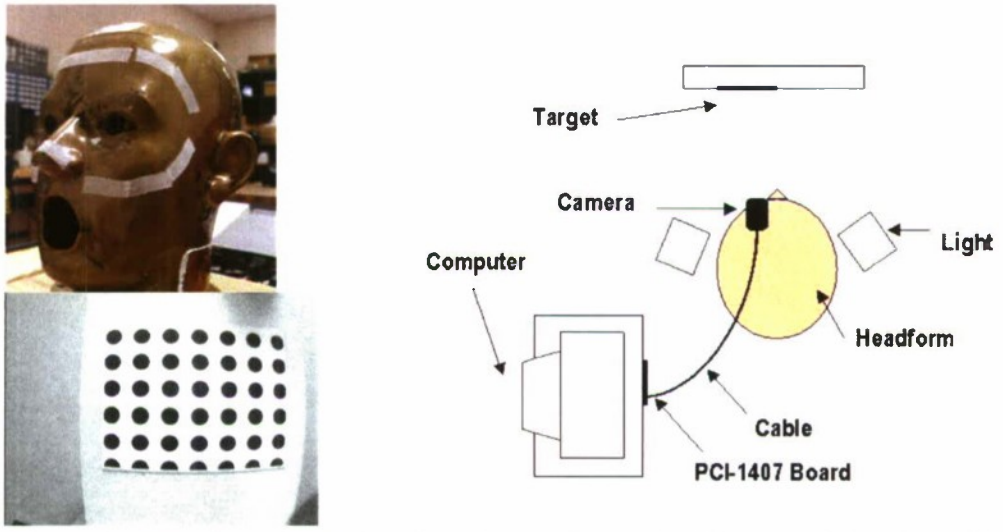

Figure 1. Headform, target, and system schematic. The metal headform is shown with the two cameras mounted in the eye-sockets. The schematic shows the placement of the target in front of the headform.

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[1] Caretti, D.M.; Coyne, K.M. *Development of an Objective Method of Respiratory Protective Mask Lens Fogging: Data Acquisition and Image Processing Proof of Concept*; ECBC-TR-333; U.S. Army Edgewood Chemical Biological Center: Aberdeen Proving Ground, MD, 2003; UNCLASSIFIED Report (AD-A417 285).

[2] Caretti, D.M.; Coyne, K.M. Methods and Apparatus for Assessing Visibility Through an Optical Material. U.S. Patent 7,538,800, May 26, 2009.

Two miniature, charged-coupled device (CCD), black and white video cameras (30mm (W) x 30mm (H) x 26mm (D), 92º Field-of-View) (Model VM1030A, Circuit Specialists, Inc., Mesa, AZ) were placed in the left and right eye-sockets of a metal headform. A Pentium computer with National Instruments (NI) (Austin, TX) IMAQ Vision Builder 6.0 and LabVIEW 6.1 software was used to acquire and process images captured from a PCI-1407 data acquisition board (NI). A photography light (Lowel Pro-Light, Lowel-Light Manufacturing, Inc., Brooklyn, NY) with a 125 W halogen bulb supplied the lighting. A target image that consisted of a series of 2.5 cm diameter black circles was placed in front of the headform. The program is not currently configured to assess the entire lens, just one region of the lens. Therefore, only two circles are used for the test. The left lens uses the circle three in from the left and three down, while the right lens uses the circle three in from the right and three down. A custom-developed LabVIEW program was used to determine the mean pixel intensity of the target circle. When fogging occurs on the lens, the image of the target circle becomes grayer, and the pixel intensity decreases. The program related the pixel intensity to a Snellen visual acuity (e.g., 20/20) using a calibration curve.

The metal headform was heated by mounting a 5 cm by 25 cm Kapton band heater (Cole-Parmer Instrument Co., Vernon Hills, IL) on the base of the neck of the headform using a high temperature silicon sealant (DowCorning, Midland, MI). A Digi-Sense Temperature Controller R/S (Advanced Model C-89000-10, Cole-Parmer Instrument Co.) and thermistor (Model 409B, YSI, Inc., Yellow Springs, OH) placed on the inside surface of the headform at the forehead were used to maintain the forehead surface temperature of the headform at 32 °C throughout the test. The headform was partially covered with a headsock made of an absorbent material that was saturated with water. A dual-channel peristaltic pump (Model U-77120-40, Cole-Parmer Instrument Co.) delivered a constant flow of water to the headsock at a rate of 0.5 mL/min through a small bore tube. The end of the tube was placed on the head sock ~2 cm from the peripheral seal of the mask near the center of the headform. The flow rate was low enough that the material remained saturated, but water did not run off the surface. A breathing pump (Computerized Breathing Simulator, Fenzy, France) was connected to the distal end of the mouth tube of the headform. The pump delivered ambient air (21.5 °C, 25% RH) to the headform on inhalation and heated, humidified air (37 °C, 100% RH) on exhalation with a tidal volume of 1 L at 15 breaths/minute.

2.2 System Calibration

Visual acuity foils (Bangerter occlusion foils) (Fresnel Prism and Lens Company, LLC, Scottsdale, AZ) were mounted on six pairs of clear safety goggles and six full-facepiece APRs to create 12 Snellen visual acuity conditions. The foils were calibrated during prior unpublished human subject testing. The goggles had acuities of 20/20, 20/23, 20/33, 20/48, 20/51, and 20/62; whereas, the foils mounted on the respirators had acuities of 20/19, 20/20, 20/56, 20/71, 20/147, and 20/429. Each pair of goggles or respirator was placed on the test headform, and the mean pixel intensity of the target circle was measured through each camera lens. An exponential regression equation was fitted to the data using SigmaPlot 2004 for Windows Version 9.0 (Systat Software, Inc., Chicago, IL) to determine a calibration equation for each camera.

2.3 Respirator

The U.S. Army M40A1 APR, shown in Figure 2, was used for the trials. The filter canister was mounted on the left side for all trials. The inhalation air flows through the filter and is then directed across the lens surface by a deflector and valves in the nose-cup.

Figure 2. U.S. Army M40A1 APR used in the study. The deflector and nose-cup are shown in the middle photograph. The right photograph shows the deflector and the nose-cup inlet valve (the nose-cup is pushed down to show the valve location).

2.4 Anti-Fog Solution

Pluronic F127 Block Co-polymer Surfactant powder (BASF Corp.) was used to make the anti-fog solution. The solution consisted of 3 g of powder mixed in 100 mL of distilled water.

The lenses of the APR were treated with the anti-fog solution using the following steps. First, several drops of solution were placed on the lens. Second, a lint-free wipe was used to wipe the lens. Third, several drops of solution were placed on the lens, and the liquid was spread with a gloved finger. Fourth, the lens was wiped using the same wipe from the second step. Finally, the lens was allowed to dry before testing commenced. The lenses were cleaned, and the anti-fog solution was re-applied after each test exposure using the same procedure. There is no standard application method for the Pluronic surfactant solution. This application method was based loosely on instructions found online for applying several different commercial off-the-shelf (COTS) anti-fog sprays and solutions. Various application methods were tried. The resulting method comprises several techniques that resulted in a fairly uniform application of the solution that prevented streaks on the dried lenses.

2.5 Coating Evaluation

The test APR was placed on the heated (32 °C), wetted headform in an environmentally controlled room (21.5 °C, 25% RH). Ten minutes elapsed to allow the impact of the heat and humidity to take effect. At the end of the 10 min, the initial snapshot and mean pixel intensity were obtained. The breathing pump was started. A snapshot and the mean pixel intensity were collected every 10 s for 2 min. The calibration equation was used to convert the mean pixel intensity to a Snellen visual acuity denominator. Snellen decimal visual acuities were then calculated by dividing 20 by the denominator. Each of three APRs was tested three times. The two conditions were full-facepiece APR with untreated lenses and APR with treated lenses. The APR with untreated lenses were tested first.

2.6 Statistical Analysis

The airflow across the respirator's lenses is different, so each lens was analyzed separately. A two-way analysis of variance (ANOVA) at the p = 0.05 level was performed to determine whether the Snellen decimal visual acuity differed between the two independent variables and whether there were any interactions between the factors. The Holm-Sidak pairwise multiple comparison procedure was used to identify whether lens treatment differed at set times.

3. RESULTS

3.1 Calibration Equations

The calibration data and best fit exponential curves are shown in Figure 3. The equations for the left and right cameras, respectively, were as follows:

Snellen Acuity Denominator = 0.59 exp (0.03 * Mean Pixel Intensity) (1)

Snellen Acuity Denominator = 0.72 exp (0.03 * Mean Pixel Intensity) (2)

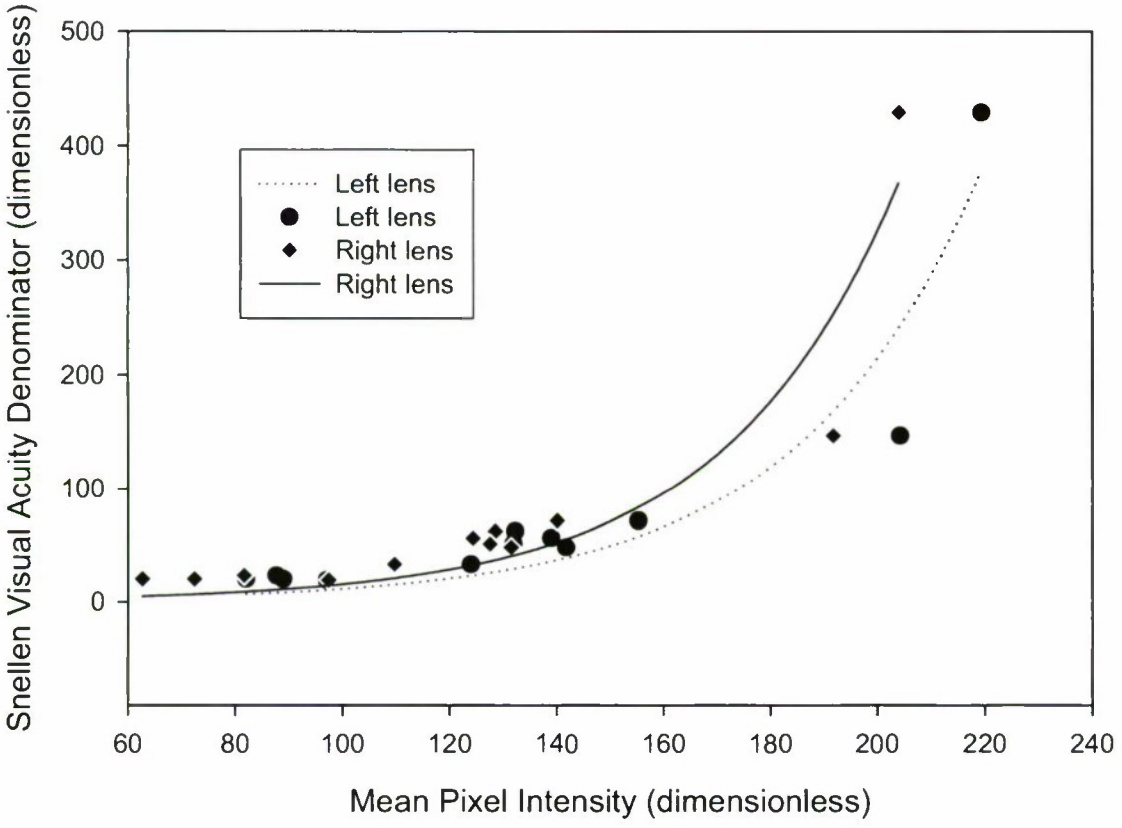

Figure 3. Calibration data and best fit exponential curves for the two cameras.

3.2 Coating Evaluation

Sample images obtained with the left camera for the treated and untreated lenses at the start and end of the test are shown in Figure 4.

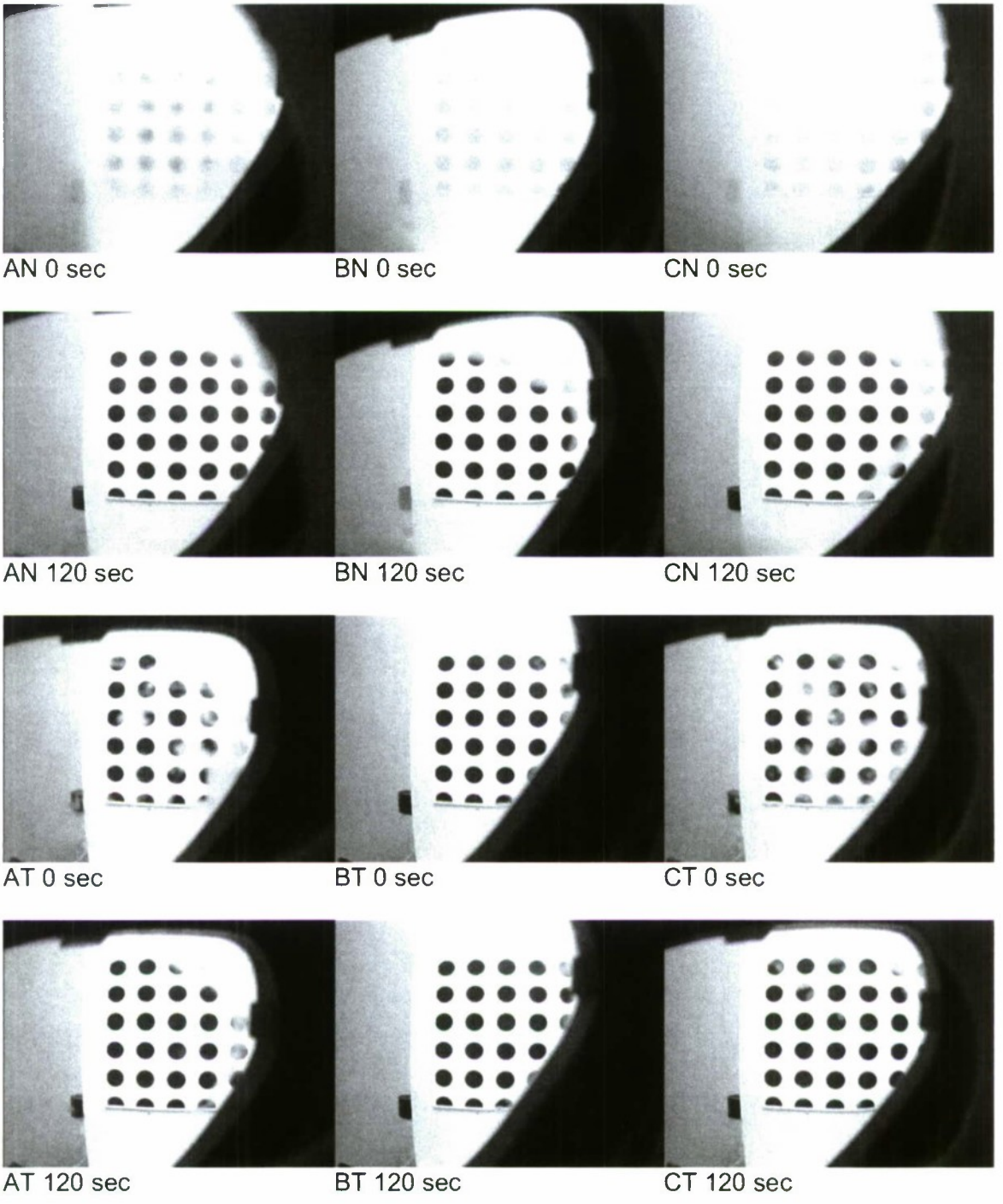

Figure 4: Sample images captured during the trials. Images are shown for each of the three respirators (A, B, and C) with either treated (T) or untreated (N) lenses at the beginning (0 s) and end (120 s) of the trial.

The mean pixel intensity during the 2 min trials is shown in Figure 5.

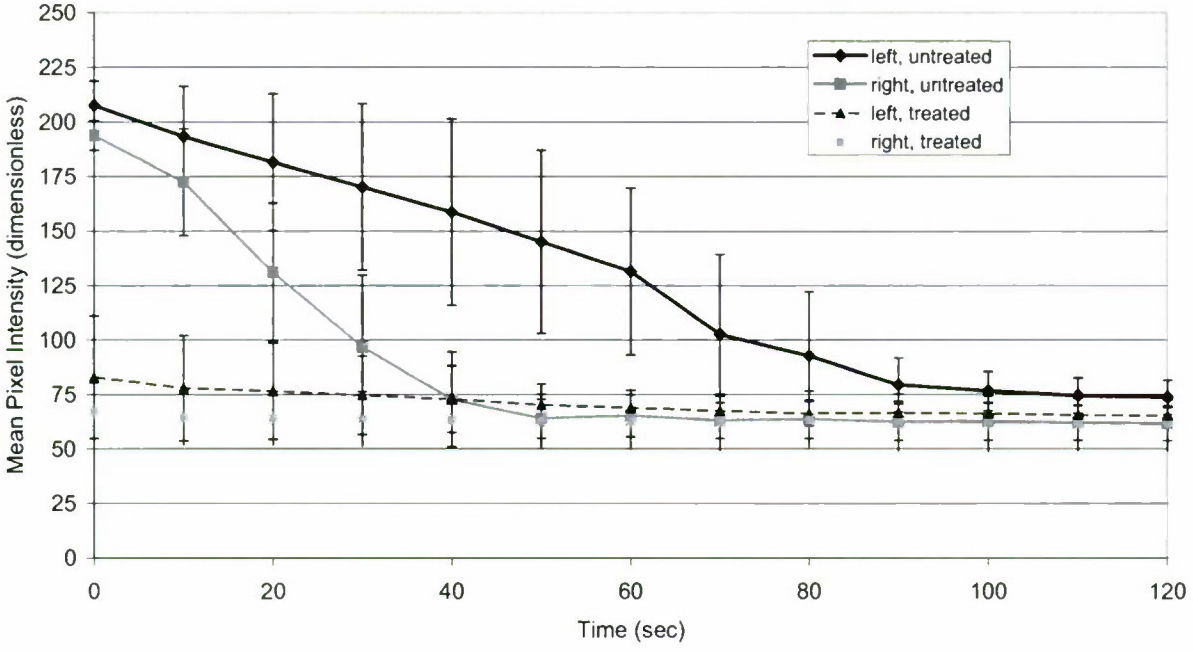

Figure 5. Mean pixel intensity for the left and right cameras over time.

The pixel intensities were converted to Snellen visual acuity denominators using the calibration equations. These values are shown in Figure 6.

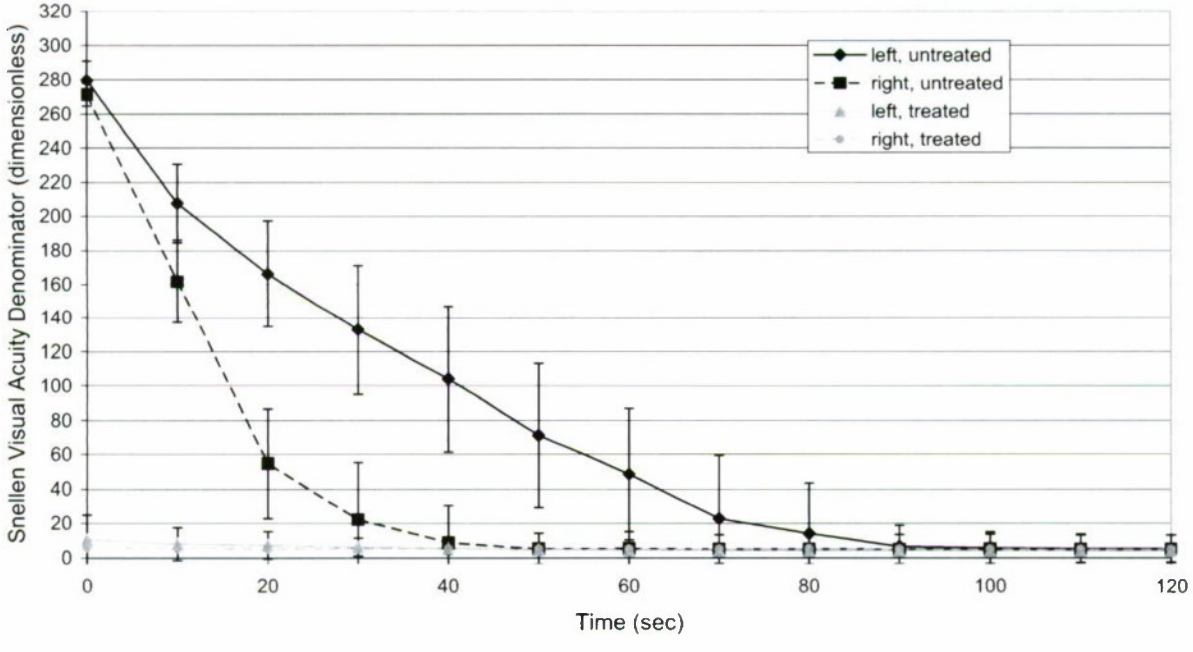

Figure 6. Denominator of the Snellen visual acuity for the left and right cameras over time.

The calculated Snellen decimal visual acuities are shown in Figure 7.

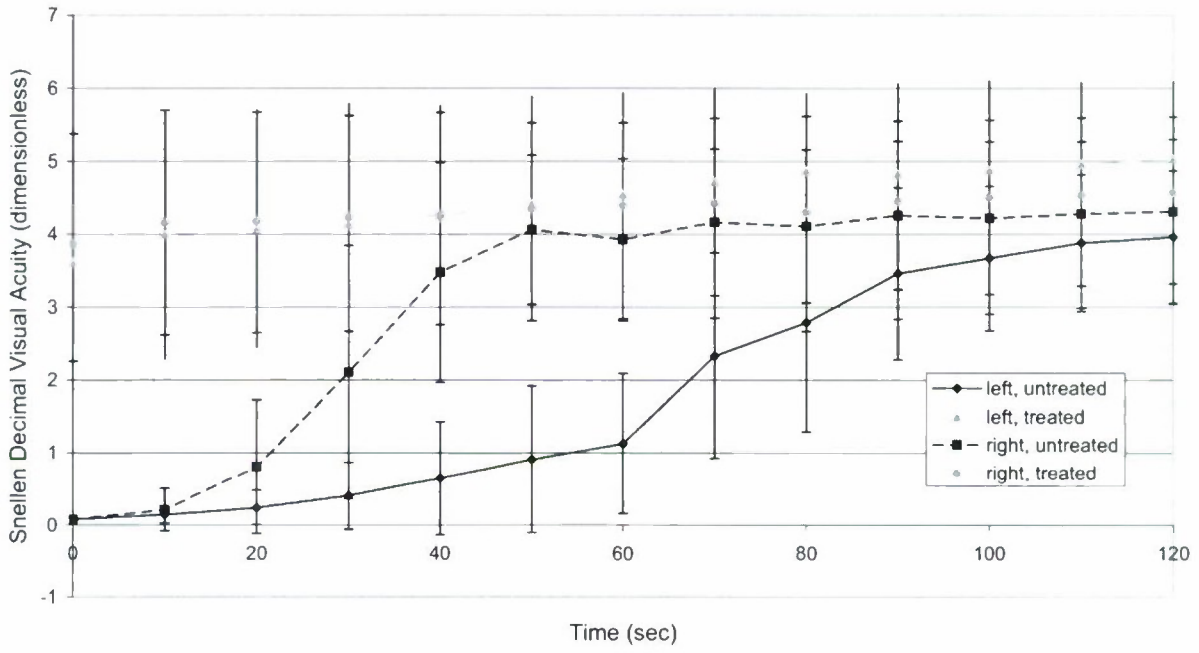

Figure 7: Snellen decimal visual acuity over time for the left and right cameras for treated and untreated lenses.

3.3 Statistical Analysis

The ANOVA for the right lens indicated that main effects of time and treatment were statistically significant and that there was a statistically significant interaction between the two. For the left lens, the interaction between the two main effects was statistically significant as was the main effect of treatment. Time was not a statistically significant effect for the left lens. However, when the interaction between two variables is significant, the interaction is assessed, not the individual main effects.

The Holm-Sidak post-hoc method was used to perform all pairwise multiple comparisons. Differences between treated and untreated were assessed at each time increment. For the right lens, there were statistically significant differences in decimal visual acuity between treated and untreated conditions for times 0 - 40 s, inclusive. Beyond 40 s, there was not a statistically significant difference. Statistically, for the left lens, the treated lens had significantly higher decimal visual acuity than the untreated lens for times 0 - 60 s.

4. DISCUSSION

Average initial Snellen visual acuity for the untreated left and right lenses were 20/254 and 20/261, respectively. For the treated lenses, average acuities were 20/6 and 20/5 for the left and right lens, respectively. The Holm-Sidak test indicated that the surfactant coating significantly decreased the initial fogging of the lenses. Over time, the difference between the two decreased until there was no significant difference between the treated and untreated lenses. This was likely due to the fact that the respirator is designed to have the filtered inhalation air flow across the lenses to decrease fogging. In fact, at 30 s and beyond, the

Snellen acuity for the untreated lenses was better than 20/20 for the right lens, while the acuity of the left lens exceeded 20/20 at 60 s and beyond.

The snapshots in Figure 3 showed the amount of fogging for some of the tests. The treated lenses do show some fogging, particularly on the periphery of the lens. Because the image processing system only examines one section of the lens, this partial fogging may or may not have been detected. The fact that only one part of the image is analyzed is also likely the reason for the large standard deviations in pixel intensity and the corresponding visual acuities for the treated and untreated lenses. However, the treated and untreated lenses show qualitative differences in vision, with drastically decreased fogging for the treated lenses.

5. CONCLUSIONS

The solution of 3 g surfactant powder mixed with 100 mL of distilled water was effective at decreasing lens fogging for the conditions tested. Further testing will be required to determine the efficacy of other concentrations or the impact of other environmental test conditions.